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Attachment No. 1 to
[redacted]-0221/64

This memorandum has to do with the microscopes that are used by the photointerpreters at NPIC to inspect the KH-4 [redacted] material. I never cease to be impressed with the fact that the final output of the whole vast photographic reconnaissance system comes out of the the eye-pieces of the microscopes and that the security of our country depends to a major extent upon the visual performance of the photointerpreters who look through these instruments. Surely as much care should be given to this final stage of the reconnaissance system as to any other part of it. I was particularly eager, therefore, to tour the photo interpretation area at the time of our last Panel meeting. I wanted to see whether the rooms used by the photointerpreters and the equipment used by them differed in any essential way from the room and the equipments used in the display and demonstration room where we have seen the various materials. The impression that I got during our tour is that the equipments are essentially identical and that the rooms are essentially similar, although in almost all cases the photointerpreters were working with room lights dimmed or even extinguished. This, of course, is as it should be.

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There was no opportunity to assay the condition of the equipment in the rooms we visited. Maintenance work was in progress on one microscope at the time of our tour. I hope that the equipments used by the photointerpreters are better maintained than the ones in the display room.

I was surprised to find that very few of the photointerpreters whom I observed at work were shielding themselves from the glare of the light from the large tables over which the films are spread. In the absence of

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tight fitting eye cups this glare can definitely reduce their visual performance. I noticed that several of the interpreters were wearing eye glasses and that they kept these on while looking through the microscopes. This of course defeats part of the optical design of the microscopes, since there is one and only one place where the pupil of the eye can be placed in order to use the system in the way that it has been designed. The exit pupil of the microscope should, of course, coincide with the pupil of the eye of the observer and when this is done he not only sees the full field produced by the eye piece, but he also sees it with the best correction of which the optical system is capable. Ordinarily this can not be done by an observer wearing eye glasses. In my earlier memorandum I urged that the eye pieces of these microscopes be changed so that a photointerpreter can set his own opthalmic correction on the eye piece, thereby personalizing the microscope and making it unnecessary for him to wear corrective lenses while looking through the instrument. I emphasize again the desirability of this practice. The interpreters should follow the procedure which is standard in the Armed Forces for lookouts; they are instructed to set their opthalmic correction on the diopter rings of the eye pieces rather than to attempt to set these adjustments by means of their visual impressions. It has been demonstrated by physchophysical tests that high scores in visual performance are obtained this way than if the observer is allowed to adjust the eyepieces in any way he wishes. If the interpreter's opthalmic examination has been correctly done, he will not only see the picture better, but he will experience less eye fatigue in this way than if he wears his own glasses and adjusts the eyepieces in accordance with his own ideas.

None of the present microscope eyepieces are able to provide the whole opthalmic prescription, including cylinders and prisms. Eyepieces with this capability should be provided. Uncorrected astigmatism can drastically reduce visual performance; the effect is insidious because the observer seldom realized that his retinal image has been deteriorated by astigmatism unless the magnitude of his astigmatism is considerable. In my memorandum of 25 February 1964 I strongly urged that means be provided for detecting and correcting small amounts of astigmatism that are ordinarily considered sub-clinical. I am confident that physophysical studies of observer performance will demonstrate that sub-clinical amounts of the astigmatism will make a considerable difference in the interpretation which can be made of partially resolved objects, and that this statement is true regardless of degree of the experience which a given interpreter may bring to bear on the task. Obviously, the better look he has at what is recorded on the film the better chance he has to extract a maximum amount of information from it. In my opinion the Agency could very well stand to support a physophysical investigation of the best techniques for looking through these microscopes. It is my belief that some rather shocking figures would be found if valid measures of visual performance were made to test some of the topics I have discussed above and in my previous memorandum .

I had an opportunity during our recent tour of the photo-interpretation rooms to talk with only one of the interpreters, and I regret to say that I do not know that man's name. He was a senior person who wore glasses

at all times including when he was looking through the microscopes. He was obviously presbiopic since his glasses were bifocal, and this was obvious also because his grey hair indicated an age in which presbiopia is inevitable. The binocular eyepieces of the microscope in his laboratory appear to be of the design which places the virtual image at reading distance rather than at infinity. Thus, even if he were ematropic he would need glasses in looking through the microscope in order to correct his presbiopia. If this were not done and the virtual image produced by the eye piece was placed at the reading distance by means of focussing the entire microscope up and down with respect to the photograph then his accomadation convergence relation would be falsified because his eyes would have to converge for near but accomodate for far and this is an unnatural and tiring situation which very few individuals can tolerate more than momentarily and even then visual performance tends to be degraded. Therefore, there is no question that this man needed his reading glasses in order to look through the microscope and according to what he told me he had other visual defects which the prescription of his glasses purported to correct. I noted that he was wearing tinted lenses for looking through the microscope and this interested me because there should be no reason for this to be necessary if the quality of the light coming through the microscope is right. He said that he felt it necessary to wear tinted lenses in order to achieve visual comfort and he attributed the discomfort which he experienced without tinted lenses to the fact that flourscent lamps are used in the illuminator beneath the microscope. If I understand him correctly he blamed flicker from these lamps for his discomfort, and he

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attributed the comfort he associates with tinted lenses to their ability to make this flicker less noticeable. I can scarcely believe that his reasoning is valid although I feel sure that he is more comfortable with the tinted lenses than without them. I believe that the comparatively small amount of light which is absorbed and, therefore, lost from the system by the tinted lenses would produce no very great comforting effect for him if the lenses were neutral. For example, he undoubtedly uses the Deming-rheostat on the light box to control the brightness of the scene in which he looks and this should accomplish for him anything that neutral density filters could do in his spectacles. I strongly suspect that the comfort he attributes to tinted lenses arises from the change in the spectral quality of the light coming through the microscopes. As I pointed out in my earlier memorandum the system seems to be afflicted by chromatic abberration, particularly at high power. It is as if the spectral quality of the light summed by the designer of the microscope lenses was quite different from that which is actually being used to illuminate the film. If this is the case, then of course the apparent chromatic abberations of the system might be much greater than in the case of say incondescent light if, in fact, this was the illuminate that was assumed in designing the optics. In any event the abberations of the systems should be studied and improved in any way that is possible. It may be that the apparent chromatic abberation will disappear if the observer does not wear spectacles and, therefore, can put his eyes at the proper place so that his pupils

coincide with the exit pupil of the microscope. This is in the case of the senior photointerpreter. I need my spectacles to look through the microscope and so I cannot make the test I am suggesting. I think it would be very interesting to devise a microscope illuminating system that does not involve flourescent lamp but preferably uses some sort of filtered and cooled tungsten lamps to illuminate the small section of the picture which is being viewed through the microscope. It is my belief that if this were done the photointerpreter with whom I talked would no longer feel the necessity for using tinted lenses. More importantly I think he would be able to see better and more comfortably than he now can do. It should also be possible with an illuminator designed to produce light only on the small part of the picture actually being viewed through the microscope to produce a higher apparent scene luminence in the microscope eye piece than at present. This should be of advantage particularly at highest power where the exit pupil is smaller than is desirable. At the risk of repeating that which I have already written I think that the photointerpreter's microscopes should be personalized to him and that a study should be made of the optimum way of accomplishing this. I believe that a specially designed face mask and eye cup system could be made for each man, that this face mask and eye cup system could make use of liquid-filled cushions such as those that are used on the best earphones. It is even possible that the man could be supplied with a bite board consisting of a dental impression so that he could position his eyes automatically to the optimum position with respect to the microscope eye pieces. Just as in the case of a toothbrush a bite board is a very personal thing and I

believe that microscope binocular eye pieces could be designed in such a way that the biteboard could be plugged in so that any photointerpreter could plug his own biteboard into any microscope in the Agency and that the act of plugging it in would automatically cause the eye piece to be set at the innerpupilary distance which has clinically been determined to be optimum for the particular photointerpreter for whom the biteboard is made. It is probable that if the optical designer of the binocular eye piece could be sure that the photointerpreter would place his eyes in exact alignment with the optical system he could design a better microscope.

The use of a well-formed and accurately fitting face mask for the photointerpreter should make it much easier to use the microscope without darkening the room. The face mask would also eliminate any glare effects from the lighted table on which the film is spread. The face mask if properly constructed would also provide a head rest and contribute to the comfort of the operator. I am not convinced that a man does his best work particularly on long periods of observation unless he is provided with every possible physical comfort. There should be attention given to arm rests, head rests, seats and pads, foot rests and so on, tailored to the stature and nature of each photointerpreter.

I was delighted in talking with the senior photointerpreter during our tour to hear him say that he visits his opthomalogist at least twice a year and that ordinarily his prescription is changed and updated about that often. I would be surprised if this practice is followed by all the photointerpreters. As I said in my earlier memorandum this should not be

left up to the men themselves but the Agency should require them to have a visual examination administered by a specialist here in the NPIC building. This should be performed for all the photointerpreters on a regular routine basis. Each man should get his examination at frequent intervals regardless of his age or the individual problems which he may or may not have with his eyes. I hesitate to suggest how frequent or infrequent these examinations should be, but I suspect that in some cases the examination should be given at least every two weeks, particularly if attention is given to sub-clinical astigmatism, which may vary in a non-systematic fashion with time. Few refractionists are skilled in sub-clinical astigmatism measurements and, in fact, it may be possible to devise some special refraction techniques or equipment to facilitate the speed and accuracy and sensitivity of the clinical measurements. I would point out in closing what I want to say about this subject that if the microscopes are equipped with eye piece systems into which the full refraction can be introduced that it will not be necessary for the photointerpreter to get a new pair of lenses fitted to himself for the purpose of his job. I am sure that at present these men hesitate to spend $25 to $50 for a new pair of lenses to be used for looking through the microscope if this expense would have to be borne by them at frequent intervals. Moreover, unless some examination is made of the lenses produced by the optician who fills the prescription it is highly probable that mistakes by the optician will go unnoticed and these mistakes are much more common than is ordinarily appreciated by the general public who buy eye glasses from manufacturing opticians. At the very least

the Agency should check eye glasses to make sure that they do indeed fill the prescription called for by the opthomologist. All of these inspection problems, I repeat, would vanish if the eye pieces of the microscope were arranged to incorporate the full opthalmic correction. I realize that such eye pieces may not exist but I see no reason why they could not be designed and produced for the microscopes used by the Agency.

The microscopes and all of their associated equipments should of course have the very best maintenance. An inspection system for the microscopes should be set up (if this is not already the case) so that every microscope is inspected frequently by an expert technician who will recognize maladjustments and administer calibration tests to make sure that the diopter rings, cylinder axis scales, etc. on the opthalmic correcting eye pieces are in precise calibration. Nothing should be left to chance or to the request for service by the photointerpreter. He should, of course, be encouraged to request service whenever he feels that there is any need for it, but on the other hand , the service department should not wait for this request but make its own inspection at very frequent intervals, perhaps daily. Like any other piece of equipment, microscopes and eye pieces can get out of adjustment.

It would be interesting to check the contrast rendition of some or perhaps even all of the microscopes used by the Agency. Contrast reduction due to scattering or imperfect lenses or lens surfaces or to deposits on the eye piece surfaces can degrade visual performance, often in an insidious way. This should not be left to chance for measurement techniques

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can be established to verify that the overall contrast rendition of the microscope is up to standard. I feel that there is just as much reason to check and maintain the microscopes and insit on their optimum manner of use as it is to maintain, check, and correctly use the cameras that make the pictures, inasmuch as the final output of the whole system is the light that comes out of the eye pieces of these microscopes. Finally, I think it should be urged that a study be undertaken to review the whole question of viewing conditions in the microscopes, to review the design of the instruments themselves in the hope that improvements can be made in their optical or mechanical design by virtue of releasing certain optical requirements upon the lens designer and thereby enabling him to shift his compromises in some direction that will gain visual performance for the particular task of inspecting the pictures on which these particular microscopes are used. Like any form of engineering the final product is the result of compromises. Relaxation of any requirement makes it possible for the designer to make an otherwise impossible improvement elsewhere. Unless such a design review has been made, I believe that there is a potential reward for the Agency in having such a study conducted. Moreover, it may be possible to devise improved techniques for using the microscopes. Perhaps incorporating some of the thoughts I have attempted to put into this and my previous memorandum and perhaps by generating other ideas as the result of a review and a critical study of the particular viewing task

at hand, it should then be possible to provide instructions for the photointerpreters on the best means for using the microscopes and using their eyes for inspecting photographic materials by all of the available means, whether through the binocular microscopes or with a simple magnifier or by naked eye or through the film viewers.

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This memorandum concerns the penetration of atmospheric haze. No statistics are known by me on how frequently the U-2 and satellite pictures are limited by atmospheric haze, but I strongly suspect that on many of the cloud-free occasions when the photographic quality is poor, atmospheric haze is responsible. Such haze lowers the apparent contrast of the scene as observed by the cameras but does not otherwise reduce the resolution potentially obtainable, since the image-forming light traverses the atmosphere without being scattered. Contrast amplification sufficient in amount to overcome the atmospheric contrast reduction would, in the absence of noise, result in images of excellent quality even under conditions which are presently found to be unsuitable for photographic reconnaissance. I suspect that atmospheric haze is a major component of the observed variability of the photographic reconnaissance material.

In quite another connection, the long-range terrestial photography carried out by the clandestine services under DD/P are also affected by atmospheric haze. Since some of the long-range terrestial photography is accomplished at ranges of 10-18 miles there are many circumstances when atmospheric haze must limit the ability of such photographs to be made. In such cases, contrast amplification could produce pictures under circumstances when no pictures could otherwise be obtained. Thus, both the clandestine services of the Agency and the reconnaissance activities could be served by the development of contrast amplification techniques to supplement photography.

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There seems little likelihood of achieving photographic means for sufficient contrast amplification to be of significant advantage. In the case of horizontal photography, through a uniform hazy atmosphere a contrast amplification of the order of 50 is necessary to double the range at which objects can otherwise be photographed. Photographic contrast amplification of this magnitude seems to be extremely unlikely if for no other reason due to the point-to-point variability of the characteristics of photographic materials. Very stringent exposure and processing requirements also make high photographic contrast amplifications unlikely to be practical, even if they can be achieved.

Electronic (television) techniques of image conversion appear, however, to offer the possibility of getting manageable contrast amplifications of 50 and perhaps 500. Spectacular photographs of otherwise invisable scenes might be accomplished in this way. It is too early to estimate the practical aspects of this possibility although it does not seem at the outset to be unsurmountable or to necessarily impose equipment requirements that could not be met in practical ways. Certainly reconnaissance photography from aircraft including both the U-2 and the Oxcart could look forward to contrast amplification using television-type image conversion equipment in conjunction with photographic or magnetic tape recording systems. It is entirely possible also that an electronic telescope might be devised for direct visual use both terrestially and from aircraft.

All of these possibilities stem from the fact that television-type electronic viewing equipment can be made that is essentially photon-limited in its signal to noise properties. The best image orthicon televison equipment is very nearly so limited at the present moment. Image orthicons cannot, however, be used to record bright images on their cathodes because of electronic saturation associated with high light levels. When image orthicon systems are used outdoors in daytime, small aperture lenses or neutral filters are used to produce images on the photo cathodes that are vastly smaller in photon content than would be possible in full daylight if vast lenses were used. Since the signal to noise ratio of a photon limited system improves as the square root of the number of photons used to construct the image all else being equal, an improvement in signal to noise ratio from image orthicon equipment is potentially possible. Under full daylight conditions the photo cathodes of image orthicon tubes could be exposed to 1 million times as much light as can presently be used without producing cathode saturation. If it were possible to operate image orthicons at the highest possible light level without electronic penalty, an improvement in signal to noise ratio equal to the square root of 1 million (i.e. 1,000) should be possible in signal to noise ration, and, therefore, in contrast amplification. If this were done trouble would immediately be encountered due to point to point variability and sensitivity across the photo cathode (i.e. to "shading"). Fortunately, means exist for combating the shading problem. The uniformity of photo cathodes could be improved

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during the manufacture of the tubes. The extent of the improvement possible is a matter of economics, but clearly, an important degree of improvement could be achieved without unduly increasing the cost of image orthicon tubes. There are moreover effective circuit techniques for combating shading. High quality existing television systems include "shading circuits" which effectively mimimize the shading problem in image orthicon tubes and, thereby allow greater manufacturing tolerances. Various other anti-shading techniques have been suggested for television use and a careful combination of all of these means might reduce the shading problem sufficiently so that special television systems for intelligence and reconnaissance use might be produced feasibly which would permit contrast amplification of 50 or more to be achieved in a very practical way.

For nearly 10 years it has been known how to use image orthicon televison tubes in curcuitry which eliminates the cathode saturation effect and enables these tubes to be used as photon limited devices at the highest achievable light levels. My colleague, James L. Harris, devised and demonstrated two different simple and straight forward means for using standard television tubes in standard television cameras in this way. Comparatively simple circuit changes and attachments to the existing television cameras were used by Harris to demonstrate contrast amplification and signal to noise ratio improvement in proportion to the square root of the photon content of the image on the image orthicon tube. Harris holds a classified U.S. patent assigned to the Navy on this television technique. Other investigators have also pursued essentially similar approaches to the problem.

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Basically, the method used by Harris makes use of the phenomenum of reversed or negative secondary mission which can occur at the photo cathode of an image orthicon tube when an abnorma structure of potentials is applied to the various parts of the tube. If under these circuit conditions the photo cathode is flooded either with light or with electrons the saturating space charge can be dispelled. This can be a nearly instantaneous process. Harris devised a system of electronic switching of the voltages applied to the image orthicon tube such that saturation effects could be wiped out during the flyback time between each successive line scan. The additional electronic components which had to be added to a standard image orthicon field chain camera were very few. Very little development work has been done by Harris or anyone else so far as I am aware in this area. It appears perfectly possible that very straight forward and reliable saturation eliminating techniques can be devised which will enable television sustems to provide contrast amplification sufficient to more than double the range of terrestial photography or to produce high contrast pictures through hazy atmospheres which make conventional photography very poor and lacking in detail. The same techniques applying to reconnaissance systems from aircraft or from satellites could produce photographs of the ground under conditions which are obliterated completely by atmospheric haze and could potentially improve the contrast and information content of high-altitude reconnaissance photography when even modest amounts of atmospheric haze serve to decrease the intelligence potential of the photography achieved by present practices.

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It is not suggested that this electronic contrast amplification is immediately suitable for use in orbital vechicles, but it would seem that photography from U-2's and Oxcarts might be possible after only a brief period of development. It would appear also that video tape recording might be used in connection with these contrast amplifying cameras; such video tape recordings might make it easier to deal with the shading problem than if photographic recordings were used. If, moreover, image processing were the extraction of additional image information and content were desired, this could probably be accomplished from the recorded video signal without involving photographic steps and their intended granularity restrictions.

It might also be possible to compromise optical equipment design in the direction of sharp edge gradiance and superior modulation transfer characteristics at low and middle spacial frequencies and depend on analytic continuation techniques (such as those described by Harris to [redacted], [redacted] during their recent visit to Harris Laboratory) in order to achieve excellent system performance at very high spacial frequencies.

All of the technical possibilities mentioned in this memorandum seem to be interconnected. All of them represent possible avenues for future technical developments and are offered in this spirit. It would seem not impossible that giant strides can be made in improving both reconnaissance photography from high-flying aircraft and long-range terrestial photography.